

and show that when  $t_0 < \frac{L}{v}$  the volume of discharge equals  $WLrt_0$ .

In the above development it was assumed that the river was dry when the rain began. Actually this condition seldom occurs in nature. However, it will be clear to the reader that this assumption was made for simplicity, and was not at all essential for the above development. If the river is not dry at the time the rain begins, then the discharge at time  $t$  is given by the sum of the right-hand side of one of equations (3), (4), (5), (6), or (9) (the one whose range includes  $t$ ) and the discharge

when the rain begins. Obviously, it is necessary to assume here that the river is at a steady state when the rain begins.

#### ACKNOWLEDGMENT

In the preparation of this article, I am indebted to Mr. Montrose W. Hayes, Chief of the River and Flood Division, for his cooperation and encouragement.

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## THE SNOW SURVEY AS AN INDEX TO SUMMER PRECIPITATION<sup>1</sup>

By O. W. MONSON

[Montana State College Agricultural Experiment Station, Bozeman, June 1934]

The successful prediction of rainfall, whether it be a single storm or the accumulation for the entire season, involves a knowledge of where the rainstorms originate and the paths they follow. The exact origin of the rain that falls at a given place cannot be definitely traced, but it is the opinion of reliable authorities that as we advance inland from the ocean the percentage of the moisture in the air which originates directly from the ocean becomes smaller.

The following is quoted from "Forests and Water in the Light of Scientific Investigation," by Raphael Zon:

The precipitation over the land does not depend solely on the amount of water brought as vapor by the prevailing winds from the ocean. \* \* \* The moisture-laden currents soon lose the moisture which they obtain directly from the ocean, but in moving farther into the interior absorb the evaporation from the land. Hence, the farther from the ocean the greater is the proportion which evaporation from the land forms of the air moisture.

Adolph Meyer says:

It is a common misconception that almost all of the rain which falls on the land comes from moisture evaporated from the ocean. As a matter of fact, the greater portion of the rain which falls in the United States is water reprecipitated after having fallen as rain (or snow) and having evaporated from the land area. (*Elements of Hydrology*.)

According to these authorities, much of the water which falls as rain at inland points has been evaporated from the residual of previous precipitation not accounted for by run-off or deep percolation. Therefore, the amount of precipitation that occurs at a given place should depend to a great extent upon the moisture conditions on the lands over which the prevailing winds at that point blow. Moisture is picked up from lakes, reservoirs, streams, snow fields, and from swamps and other moist lands. How much is contributed by each should depend, among other things, upon its relative extent.

On the theory that conditions which affect the extent of one of these sources will affect all in about the same proportion, a pre-season measurement of the extent of one or more of the above-named sources of moisture should be an index to the amount of summer rainfall at various places located in the path of the moisture-bearing winds.

To test this theory the writer made comparisons between the water content of the snow cover on the watershed of Swiftcurrent Creek of the St. Mary River drainage basin measured early in May and the amount of rain occurring during April, May, June, July, and August at Havre, Geraldine, and other places located eastward from the snow fields. See figure 1.

The water content in inches of the snow cover in the Swiftcurrent cirque of the St. Mary River Basin was plotted for the 12-year period of record from 1922 to 1933, inclusive. The summer rainfall in inches for the several places mentioned was plotted for the same period, and the water content curve was then compared with each rainfall curve to discover if any correlation existed.

A marked similarity was observed in the fluctuations when the water-content curve was compared with the rainfall curves for Havre and Geraldine, as shown in figure 2. The rainfall record at Havre and Geraldine during April, May, June, July, and August and the water content of the snow cover in the Swiftcurrent basin measured on May 1 of each year are given in table 1.

Correlation coefficients calculated between the water content of the snow in the Swiftcurrent basin and the rainfall during April 1 to August 31 at Havre and at Geraldine give values of 0.72 for Havre and 0.71 for Geraldine, which is a high degree of correlation. This apparent relation between the water content of snow in the Swiftcurrent basin and the summer rainfall at Havre is expressed by the equation  $R = 0.177W + 4.74$ , where  $R$  equals inches of rainfall and  $W$  is the water content of the snow cover in inches. The equation representing the best fit line for Geraldine is  $R = 0.155W + 4.05$ .

The reliability of this correlation is limited by the paucity of data available over a short period of record, 12 years. To be conclusive, a much longer period should be studied. Snow surveys are a comparatively recent innovation, but their value is rapidly being recognized.

By means of these two equations the summer rainfall at Havre and Geraldine was calculated for the 12-year period from the water-content measurements in the Swiftcurrent basin and the estimated amount compared with the actual record as in figures 3 and 4. The similarity of the curves is remarkable. It may be noted that the slope of the estimated curves, that is, up or down, showing increase or decrease as compared with the previous year, is correct 11 out of 12 years for Geraldine and 10 out of 12 years for Havre, and that a forecast of "above normal" or "below normal" would have been correct in 10 out of the 12 years for each place.

But this correlation does not necessarily prove a direct causal relationship between the snow cover on the St. Mary River watershed and the summer rainfall at Havre and Geraldine. Perhaps they are associated as kindred effects of a third factor, or perhaps they show similar variations because affected by other similar though distinct underlying influences. This, however, does not detract from the practical value of the apparent relationship.

<sup>1</sup> Contribution from Montana State College, Agricultural Experiment Station. Paper No. 40, Journal Series.

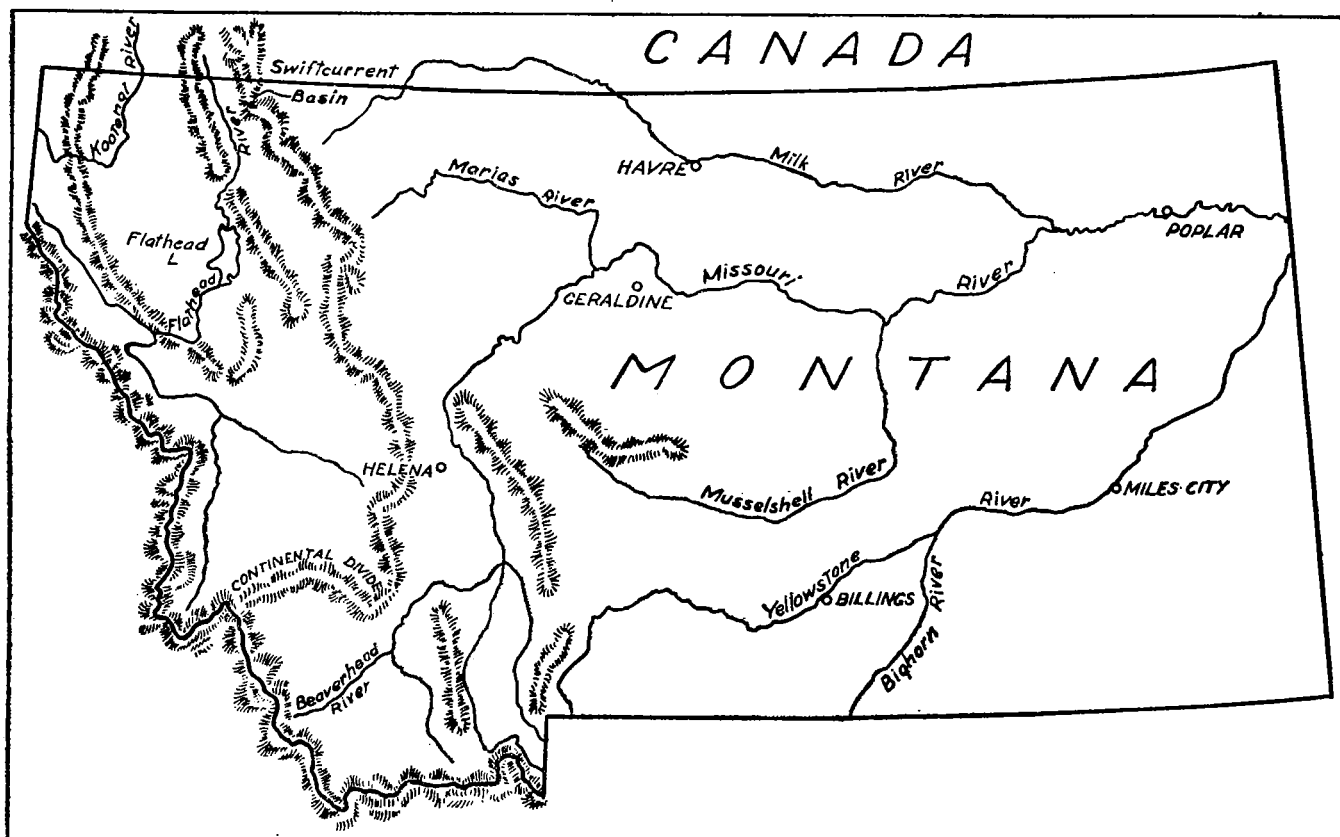


FIGURE 1.—Map of Montana showing the principal drainage systems and the location of the rainfall stations referred to.

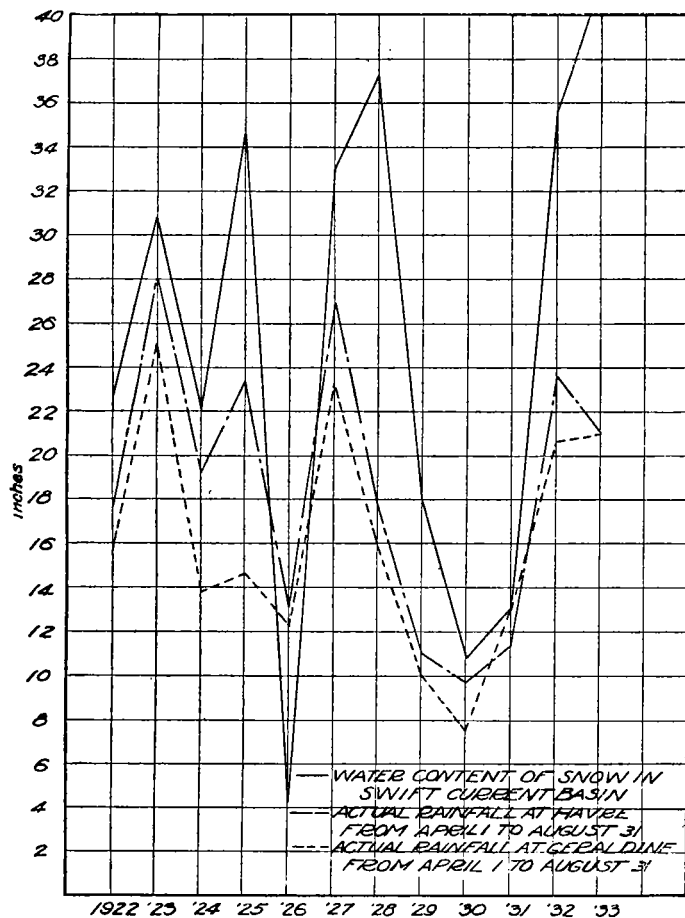


FIGURE 2.—Water content of snow cover on the Swiftcurrent watershed of the St. Mary River drainage basin compared with the summer rainfall at Havre and Geraldine, Mont.

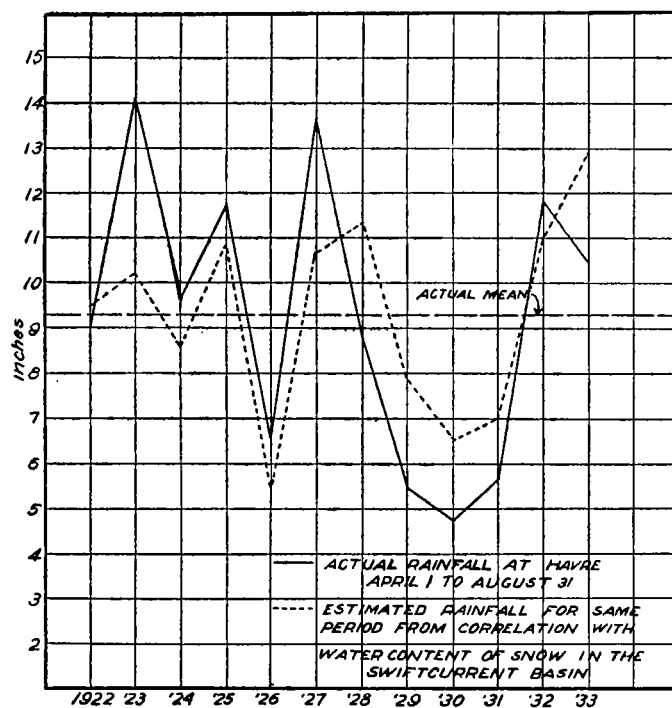


FIGURE 3.—Comparison of actual rainfall at Havre with amount estimated from correlation with water content of snow in the Swiftcurrent Basin.

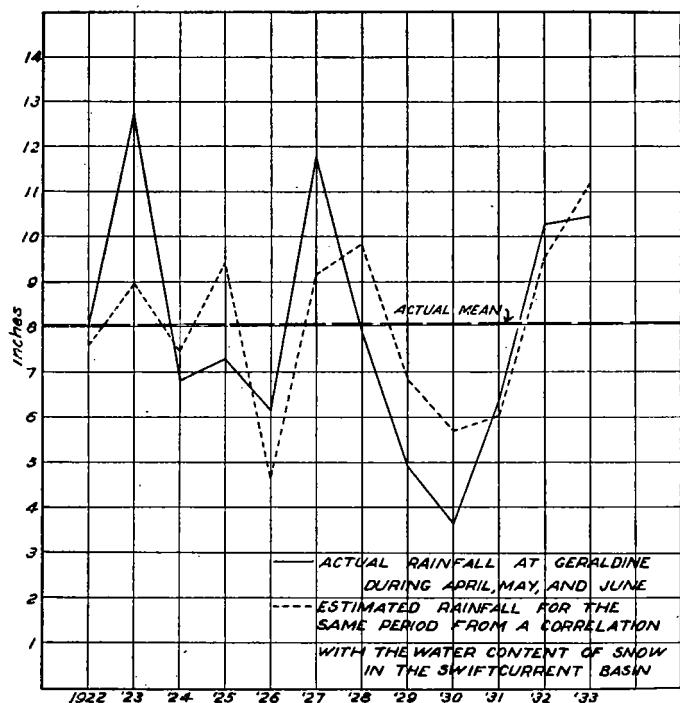


FIGURE 4.—Comparison of actual rainfall at Geraldine with amount estimated from correlation with water content of snow in the Swiftcurrent Basin.

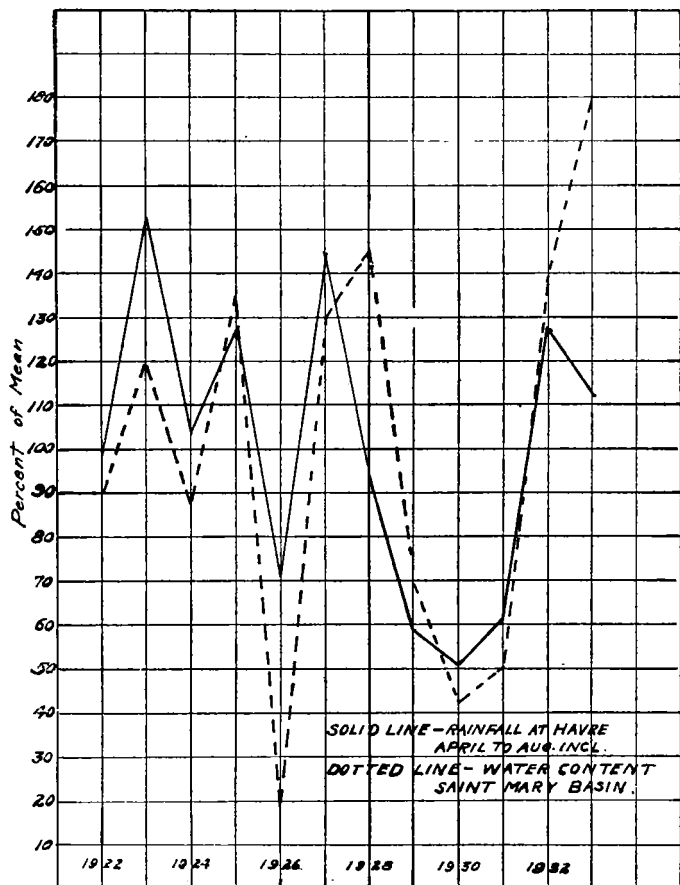


FIGURE 5.—Comparison of rainfall at Havre from April to August, inclusive, with water content of snow in the St. Mary Basin.

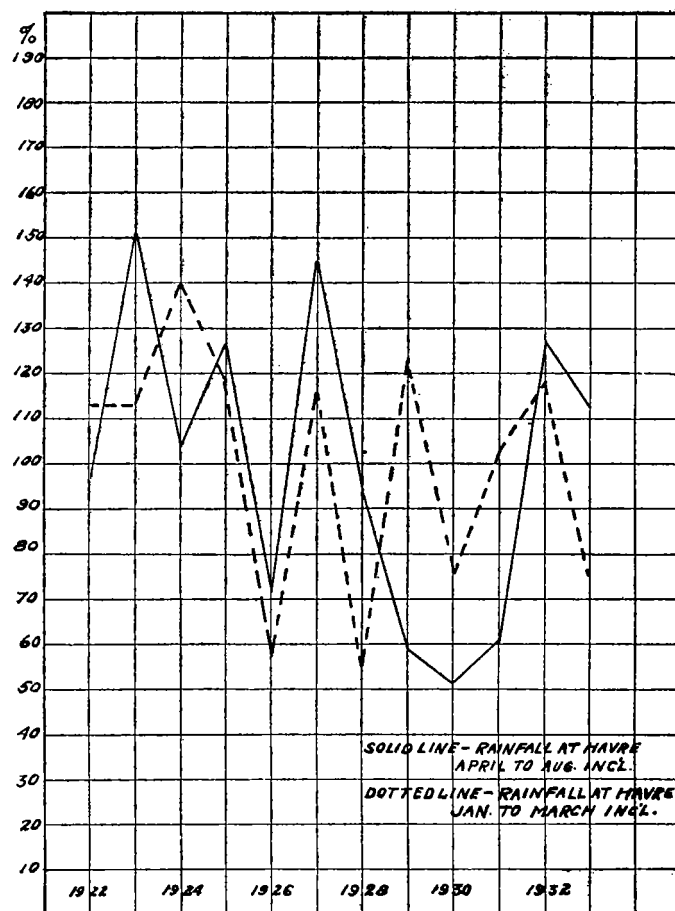


FIGURE 6.—Comparison of rainfall at Havre from April to August, inclusive, with rainfall during January, February, and March.

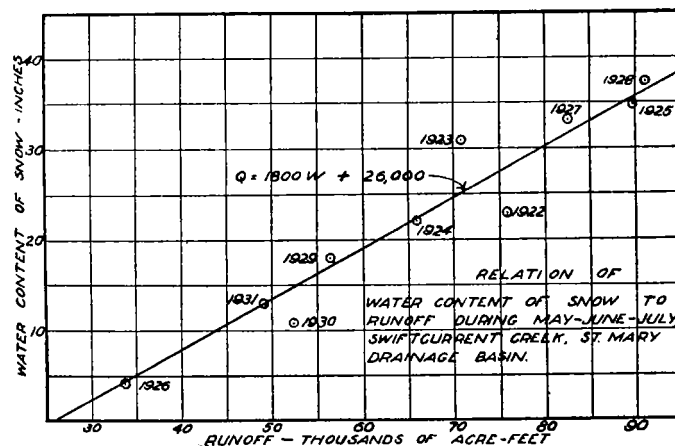


FIGURE 7.—Relation of water content of snow to run-off during May, June, July, Swiftcurrent Creek, St. Mary drainage basin (International Snow Survey, U. S. Geological Survey and Dominion Water Power and Hydrometric Bureau. Used by permission).

An indication that a third factor, a trend that tends to keep both winter and the following summer precipitation above or below normal, and thus to give them a high correlation, may be operating as a common cause is shown in the following statement from W. R. Gregg.

There is a rather marked tendency for certain characteristics of precipitation, that is, whether tending to above normal or to dryness, to persist for a considerable period of time. \* \* \* When we examine the record for Havre alone, without reference to the question of mountain snow water, we find for the period for which data are used that the precipitation from January to April, inclusive, was above the 12-year average six times, and for these years the subsequent rainfall from May to August was above the average five times. Also for the other 6 years, when the precipitation at Havre was below average for the first 4 months of the year, the subsequent 4 months also had below average five times out of the six. Thus the departure from average precipitation at Havre for the first 4 months and for the second 4 months of the year had the same sign in 10 of the 12 years covered by the period under consideration.

When the forecast is made to extend over a 5-month period, April to August, inclusive, the correlation by the snow-cover method is closer than that by the rainfall method. (See figs. 5 and 6.) The departure of the water content for the 12-year average had the same sign as the departure of the rainfall from April 1 to August 31 ten years out of the twelve, while the departure from the average of the precipitation of the first 3 months had the same sign as the next 5 months' precipitation only 8 years out of the 12. (The coefficient of correlation of the rainfall at Havre during the 3-month period, April, May, and June, with the water content of snow on the St. Mary watershed was 0.685, and that with the precipitation during January, February, and March was 0.51.) It is interesting to note that when the departure from the average of the water content had the same sign as the departure of the precipitation of the first 3 months, the precipitation from April to August was always in agreement.

Since snow-cover records are available only on a single watershed in Montana, the number of direct comparisons that can be made necessarily is limited, but the theory can be tested further in an indirect way because of the original purpose of the snow survey, namely, stream-flow forecasting. The snow survey in the St. Mary basin, for example, was inaugurated as a basis for forecasting the run-off from this watershed to estimate the amount of water available for irrigation to the various projects along the Milk River on both sides of the International Boundary.

After several years of record were obtained, the relation of the water content of the snow cover to the summer run-off from the drainage basin was found by plotting the water content in inches against the run-off in acre-feet, as in figure 7. Now that this relationship has been determined, it is possible by measuring the water content of the snow early in May to predict very closely how much water will be available for irrigation during the summer. This has been done successfully for a number of years.

Similar snow-cover run-off relations have been determined for Logan River in Utah. (See fig. 8.) Here the water content is expressed as a percent of the average for the period of record, the average equaling 100 percent. The run-off is also expressed as a percent of the mean run-off in acre-feet during the irrigation season for the same period of record. This method was chosen on the assumption that a normal snow cover will produce a normal run-off. While this assumption has not proved to be absolutely correct, the relationship appears to be close, and on the basis of this curve successful preseason forecasts have been made for several seasons as to the amount of water that would be available for irrigation to the sev-

eral canal companies diverting water from the Logan River.

These forecasts are valuable and are much in demand by the farmers and project managers on the irrigated areas along the Milk River in Canada and Montana and in Cache Valley, Utah. Similar surveys have also been established in Nevada and California.

We may reasonably assume that similar snow-cover run-off relations exist on all watersheds; therefore, it is possible to test further the theory regarding the origin of summer rainfall at a given place by comparing the summer rainfall at the desired point with the summer run-off from a watershed westward from it. Then, if a correlation is found to exist, other conditions being equal, it may safely be assumed that about the same degree of correlation exists between rainfall at the place referred to and snow cover on the watershed which apparently contributes to the run-off.

This is true between Havre and the St. Mary drainage basin, and it has already been shown that there is a correlation between summer rainfall at Havre and the water content of snow cover in the Swiftcurrent watershed of the St. Mary drainage basin. When the summer run-off

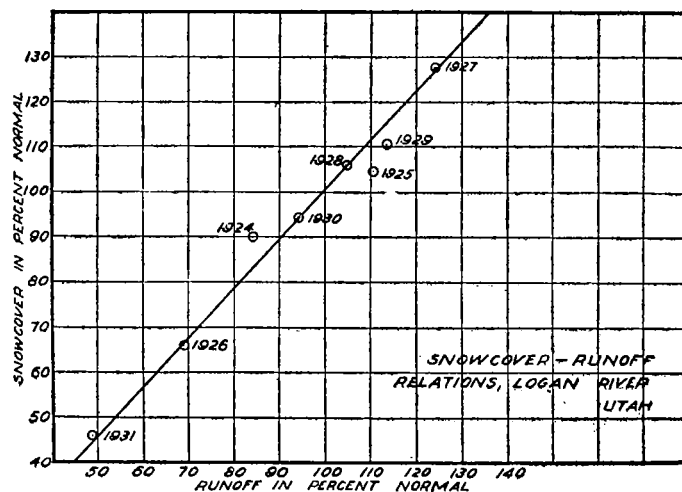


FIGURE 8.—Snow cover run-off relations, Logan River, Utah (Agricultural Engineering for February 1932).

from Swiftcurrent Creek is expressed as a percent of the mean of the 12-year period of record and the summer rainfall at Havre is represented in the same way, the correlation is also apparent. However, it does not appear to be quite so close as when the rainfall is compared directly with the snow cover. (See fig. 9.) The summer rainfall at Geraldine shows about the same degree of correlation when compared with the run-off as with the water content of the snow cover from the same watershed.

By using this indirect method of testing the theory, more data are available for use. Precipitation records are kept by the United States Weather Bureau for every part of the State. The principal streams of the State are gaged and records published annually by the United States Geological Survey with the cooperation of the State engineer. However, run-off records are not as complete as the weather report. On many important streams only short and in some cases fragmentary records are available and these are not complete enough for statistical purposes. Consequently the study is still restricted very much by lack of data.

A number of precipitation stations were chosen from different parts of Montana east of the continental divide. For each of these a record of the rainfall occurring

during April, May, June, July, and August was obtained for a period of 20 years, 1911 to 1930, inclusive. The mean for this period was calculated and summer rainfall for each year expressed as a percent of this mean.

The summer run-off from several streams was obtained from hydrographic reports for the same 20-year period and the 20-year mean was determined. Each year's run-off was then expressed as a percent of the 20-year mean for that stream, as was done for the precipitation stations.

These precipitation and run-off records were then plotted, and since each was expressed as a percent of its mean the rainfall records were all comparable with the run-off records. By comparing each rainfall curve with each of the run-off curves in turn, any existing correlation was quickly discovered.

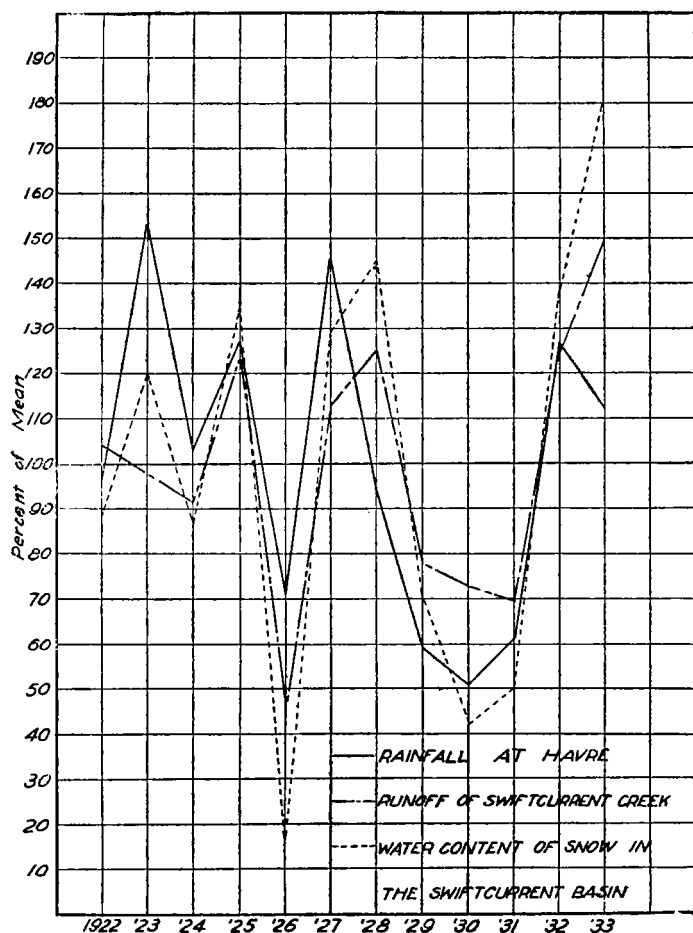


FIGURE 9.—Rainfall at Havre compared to run-off of Swiftcurrent Creek and to water content of snow in the Swiftcurrent Basin.

In this way similarity was discovered between the rainfall curve at Miles City and the run-off curve from the Beaverhead River. The rise or fall was almost identical for the two curves during a 7-year period from 1918 to 1924; and for four more years, 1925 to 1928, an increase or decrease in run-off from the Beaverhead River was reflected in an increase or decrease in summer rainfall at Miles City. Assuming that the run-off from the Beaverhead could be forecast by means of the snow survey, it could be used to predict the amount of summer rainfall at Miles City, as shown in figure 10, by multiplying the estimated percent of mean run-off by 8.55, which is the mean rainfall at Miles City, and dividing by 100.

Why there is such a high degree of correlation for 11 successive years from 1918 to 1928 and none at all from 1912 to 1918 nor during 1929 and 1930 cannot be ex-

plained from the data at hand. It may be that conditions which affect the extent or amount of one of the sources of the summer rainfall at Miles City do not affect all in the same proportion and therefore the assumption previously stated to that effect may be erroneous. But it is also possible that a record of the water content of snow cover on the Beaverhead watershed would show a higher degree of correlation with the rainfall than does the run-off, because the accuracy of the run-off records is affected to some extent by diversions and regulations above the gaging station. The rainfall at Havre, for example, showed a closer correlation to the snow cover than to the run-off from the Swiftcurrent basin.

When the rainfall at Miles City for the period April to August, inclusive, is compared with the rainfall for January, February, and March we find that the departure from the average has the same sign 12 years out of 20. When compared with the run-off from the Beaverhead River, the rainfall at Miles City for April to August falls on the same side of the average as the run-off 14 out of 20 years. But when the rainfall for April to June, inclusive, is compared with that of the first 3 months the departure has the same sign 16 out of 20 years (see fig. 11), while the coefficient of correlation in this case is only 0.17. The coefficient of correlation of the rainfall at Miles City during April, May, and June with the run-off of the Beaverhead River is 0.42.

These facts illustrate still further that correlation may exist with or without causal relationship. To discover a direct casual relationship, if such exists, will solve the problem of seasonal forecasting, but in the meantime these apparent correlations will be found both interesting and profitable.

The rainfall at a given place frequently cannot be correlated with run-off from a single watershed. This should not be expected from the very complex nature of the problem. It was found in the case of Helena that no single run-off curve could be found among those studied which showed very much similarity to the rainfall curve at Helena. But when the average run-off of the Beaverhead and Musselshell Rivers was taken in percent of their individual means, the resulting curve showed considerable similarity to the rainfall curve for Helena, and an estimated rainfall curve based on this correlation fluctuates up and down in sympathy with the actual rainfall curve from 1918 to 1929, inclusive, as shown in figure 12. The calculated amount agrees closely with the actual amount during 9 out of the 20 years of record; and during 16 of the 20 years the calculated value and the actual value fall on the same side of a horizontal line drawn through 7.4, the mean at Helena.

Similarly, the rainfall curve at Billings, while showing very little correlation to any single run-off curve, showed a fair degree of resemblance to a curve derived from the average run-off of the Yellowstone, Beaverhead, and Priest Rivers. The calculated amount of summer rainfall at Billings, as given in figure 13, was obtained by multiplying the mean summer rainfall, 8.1 inches, by the average percent, based on the mean of each stream, of the run-off from these three streams and dividing by 100.

The rainfall curve at Poplar also was not successfully correlated with any one run-off curve although some similarity was observed when it was compared with an average of the Big Horn and Marias Rivers shown in figure 14, where an estimated rainfall curve is compared with the actual. The correlation is poor, although the estimated amount agrees with the actual within practical limits for 9 out of the 16 years of record.

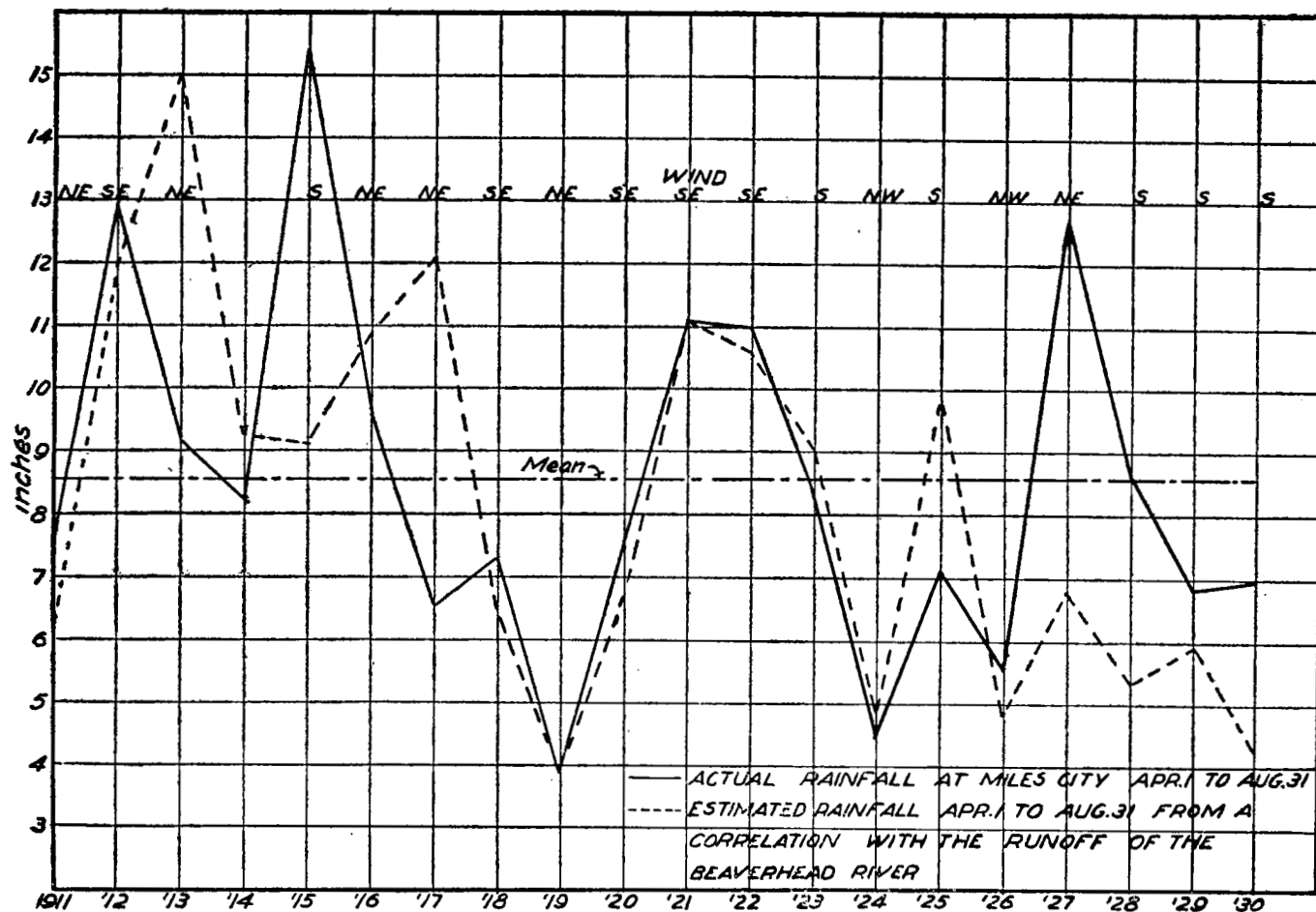


FIGURE 10.—Comparison of actual rainfall at Miles City with amount estimated from a correlation with the run-off of the Beaverhead River.

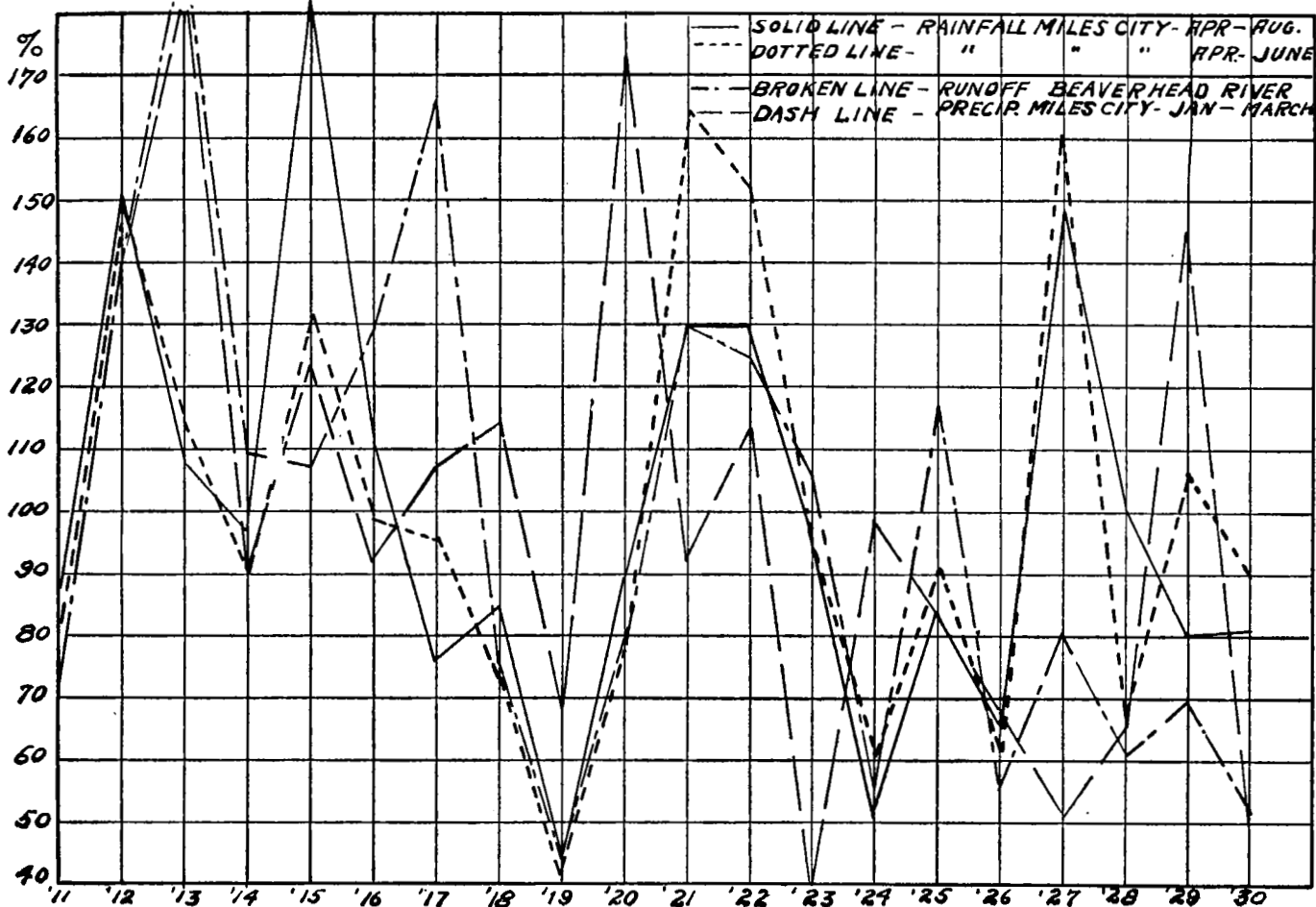


FIGURE 11.—Comparison of actual rainfall at Miles City from April to August, inclusive, and from April to June, inclusive, with run-off from the Beaverhead River and with the precipitation during January, February, and March.

The amount of summer rainfall at other points in the State seems also to bear some relation to the amount of run-off from certain watersheds in the western part of

It is possible that the stage of lakes and reservoirs, which determines their evaporation areas, would also be an index to rainfall at some particular place. When

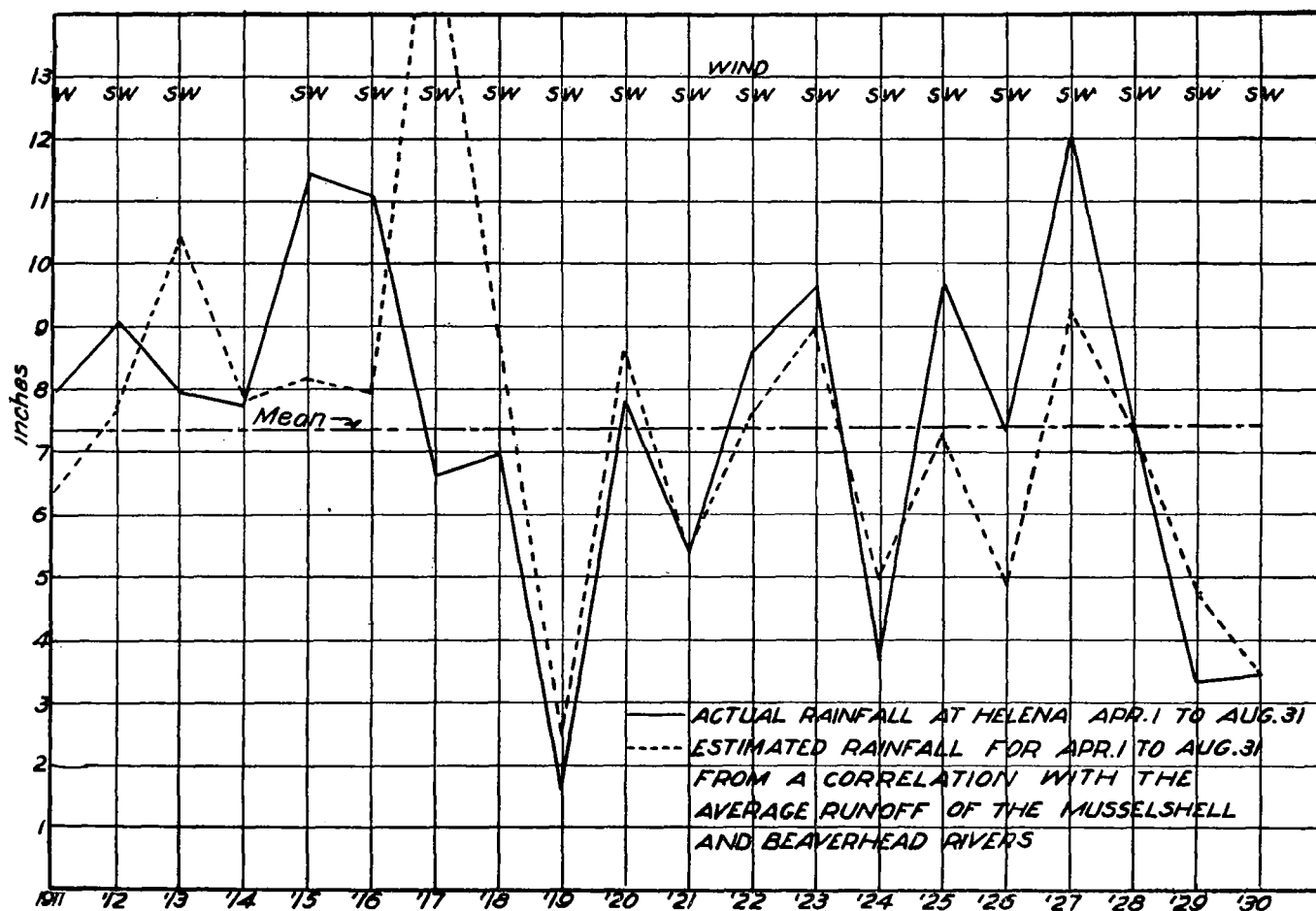


FIGURE 12.—Comparison of actual rainfall at Helena with amount estimated from a correlation with the average run-off of the Musselshell and Beaverhead Rivers.

the State, but the examples given are a sample of what may be accomplished along this line.

These correlations show that the amount of rainfall occurring at certain places varies to a marked degree with the amount of water stored in the accumulated snowcover on certain watersheds. Whether or not this is a causal relationship remains to be determined. But since the relationship exists, a pre-season survey of the snowcover over these areas will make possible a pre-season forecast of rainfall at certain places where the rainfall either varies as a causal effect of the moisture conditions over the evaporation area or is affected by the same factors which affect these moisture conditions.

Because of these correlations, it appears that a comprehensive snow survey on all watersheds would show other water-content rainfall relations from which it would be possible to predict, several months in advance, the amount of rainfall likely to occur during the summer at many places, some of which may be a great distance from the related watershed. The value of the snow survey for predicting run-off has already been demonstrated. Other information concerning the behavior of the snow blanket could also be obtained from the snow survey, which might suggest ways of improving the watersheds so as to reduce, if not eliminate, the dissipation of snowcover through too rapid melting and wasteful run-off.

combined with the snow survey this should improve correlations and make possible a greater degree of accuracy in making forecasts.

TABLE 1.—Rainfall at Havre and Geraldine and water content of snow cover in the Swiftcurrent Cirque of the St. Mary River drainage basin

Year	Water content <sup>1</sup> of snow cover as of May 1		Rainfall <sup>2</sup>			
			Havre Apr. 1 to Aug. 31		Geraldine Apr. 1 to Aug. 31	
	Inches	Percent of mean	Inches	Percent of mean	Inches	Percent of mean
1922	22.8	89	8.86	96	7.94	98
1923	30.9	120	14.18	153	12.74	158
1924	22.0	86	9.63	104	6.83	85
1925	34.9	136	11.76	127	7.30	91
1926	4.1	16	6.56	71	6.18	77
1927	33.2	129	13.50	145	11.86	147
1928	37.4	146	8.73	94	7.96	99
1929	18.1	70	5.49	59	4.87	61
1930	10.7	42	4.75	51	3.65	45
1931	12.9	50	5.69	61	6.53	81
1932	35.6	138	11.83	127	10.32	128
1933	46.2	180	10.44	112	10.46	130
Mean	25.7		9.28		8.05	

<sup>1</sup> Water content of snow measured by the U. S. Geological Survey in cooperation with the Dominion Water Power and Hydrometric Bureau, available through the courtesy of W. A. Lamb, of the U. S. Geological Survey.

<sup>2</sup> Rainfall records from the annual reports of the U. S. Weather Bureau.

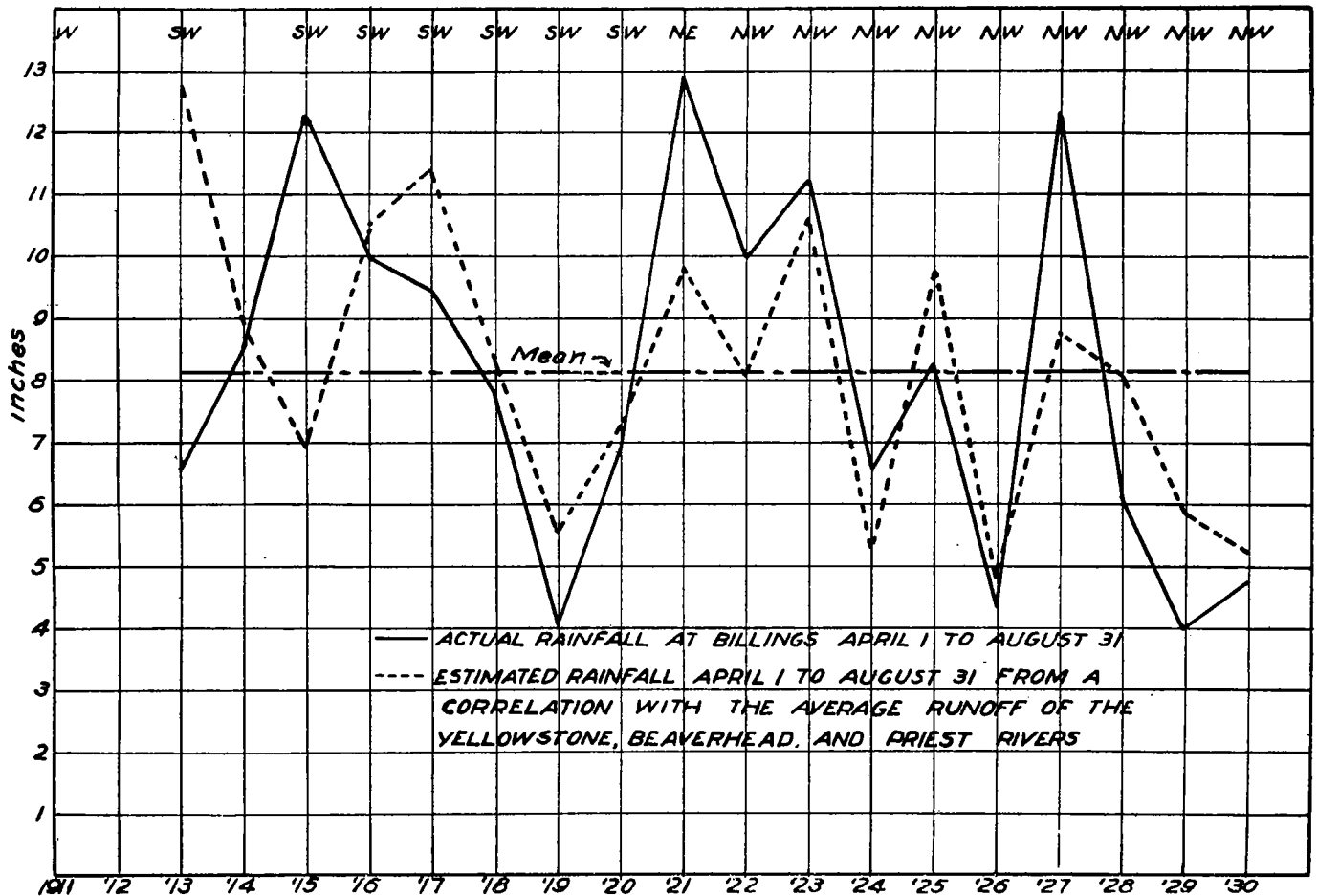


FIGURE 13.—Comparison of the actual rainfall at Billings with the amount estimated from a correlation with the average run-off of the Yellowstone, Beaverhead, and Priest Rivers.

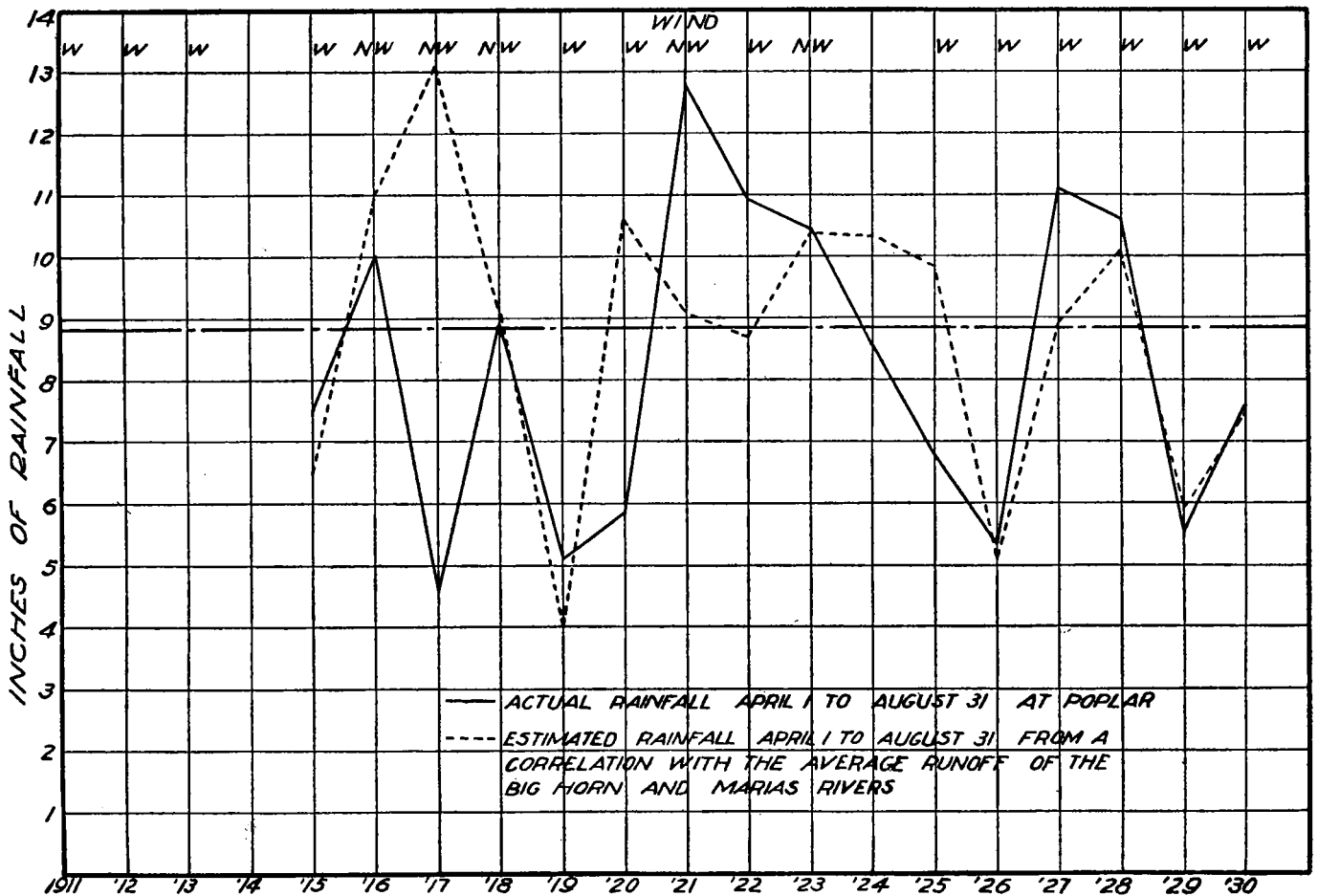


FIGURE 14.—Comparison of the actual rainfall at Poplar with the amount estimated from correlation with the average run-off of the Big Horn and Marias Rivers.

Definite conclusions cannot be drawn from this brief examination of precipitation and run-off records. A more thorough study may reveal contradictory results, or again it may give further support to the opinions which seem justified from the analysis of the available data. One thing is conclusive, which is that precipitation and run-off records are extremely valuable if kept consistently

and continuously and that more are needed. Run-off records should be kept on all streams where they emerge from the mountains and at other key points along their courses. Meteorological data taken at high altitudes and so distributed as to be representative of large areas are also needed. This study suggests another use for such data.

## TURBIDITY AND WATER VAPOR DETERMINATIONS FROM SOLAR RADIATION MEASUREMENTS AT BLUE HILL, AND RELATIONS TO AIR-MASS TYPES

By HERBERT H. KIMBALL, Research Observer

[Harvard University, Blue Hill Meteorological Observatory, Milton, Mass., September 1934]

The solar radiation intensity measurements obtained at Blue Hill during 1933 have already been published—those for January to August, inclusive, in the REVIEW for August 1933; and for later months, in the corresponding issues that followed—as a part of the radiation data that are published for a number of observing stations in the United States. In table 1 of this paper the values of  $\beta$  and  $w$  are given as determined by a method previously described by Kimball and Hand,<sup>1</sup> except that the curves given in the Smithsonian Meteorological Tables, 1931, figure 1, p. LXXXIV, and showing the percentage of depletion of solar radiation by different amounts of atmospheric water vapor, have been drawn separately on cross-section paper that permits a more open scale, and facilitates interpolation.

The first column of table 1 gives in addition to the date, the air mass,  $m$ , corresponding to the solar altitude at the time the measurements were made, or more definitely, at the moment the yellow glass screen was replaced by the red screen. The air masses for p. m. measurements are printed in italics. Each screen is usually in place for from 3 to 4 minutes. During this interval the record for the radiation intensity for the total spectrum must be obtained by interpolation.

Readings of the Smithsonian silver disk pyrheliometer made during this same interval, when divided by the scale reading of the interpolated record, give the value of unit scale on the record in gram calories per minute per square centimeter of surface normal to the intercepted solar rays. This value is also sometimes obtained from readings made just preceding or following the screened readings. An apparent progressive decrease in the sensitivity of the thermopile, as indicated by these comparisons, and especially after the advent of warm weather in 1934, was not understood, until the instrument was taken apart at the Eppler laboratory, when it was found that the space above the receiving surface of the thermopile contained several dead insects. These were removed, and the blackened surface was reconditioned. It is fortunate that frequent comparisons have been obtained between the Smithsonian pyrheliometer and the records obtained from the Eppler thermopile, so that it is possible to eliminate most, but probably not all, of the irregularities in the automatic records. Some of the discrepancies that appear in the values of  $\beta$  derived from these screened radiation intensity records quite probably are attributable to this cause.

*Determinations of the turbidity factor,  $\beta$ .*—The details of the method of determining this factor have been given in the REVIEW for March 1933, already referred to. During the summer of 1933 the transmission of the glass color filters was redetermined by both the United States Bureau of Standards and the laboratory of the United

States Department of Agriculture Bureau of Soils. In both laboratories the transmissions were found to be about 0.992 that given by Feussner's tests,<sup>2</sup> or 0.871 for the transmission of the red filter,  $RG_2$ , and 0.882 for the transmission of the yellow filter,  $OG_1$ , instead of 0.878 and 0.889, respectively, which had previously been used. Early in 1934, during cold winter weather, the transmissions were again determined at the laboratory of the United States Department of Agriculture, and the values obtained were in close accord with those given by Feussner. The difference in the two determinations at the United States Department of Agriculture laboratory is attributed to the difference in the temperature of the laboratory at the times the tests were made, it being considerably cooler in winter than in summer. What effect may be produced by the high temperatures to which the screens are subjected when exposed to the sun in summer as compared to the low temperatures under similar exposures in winter, is a problem yet to be solved. In the mean time, the values determined during the summer of 1933 are being employed. Too high values for the transmission of the screens increases slightly the differences  $I_m - I_r$ , and decreases slightly the differences  $I_y - I_r$ . The values of  $\beta$  derived from these differences will be affected in an opposite direction, i. e., slightly lower values for  $\beta I_{m-r}$ , and slightly higher values for  $\beta I_{y-r}$ . A value of  $\beta_{\text{mean}}$  that is too low gives a value of  $I_{m(w=0)}$  that is too high, resulting in too high a value for  $I_{m(w=0)} - I_m$ , and, consequently, of  $w$ . Therefore, this method of determining the water-vapor content of the atmosphere can hardly be expected to rank in accuracy with spectrophotometric methods.

Mr. H. Wexler of the observatory staff, and also a graduate student in the School of Meteorology, Massachusetts Institute of Technology, has determined from air-mass analysis maps made twice each day at the school, the type of air-mass prevailing in the vicinity of Blue Hill on days when solar radiation intensity measurements were made. The air-mass type is indicated by symbols, the significance of which is as follows:<sup>3</sup>

Symbol	Source
$P_1$ .....	Colder portions of the North Atlantic.
$P_2$ .....	Alaska, Canada, and the Arctic.
$P_3$ .....	North Pacific Ocean.
$NA_1$ .....	Modified North Atlantic.
$NA_2$ .....	$P_2$ modified in southern and central United States.
$NA_3$ .....	$P_3$ modified in western and central United States.
$T_1$ .....	Gulf of Mexico and Caribbean Sea.
$NA_4$ .....	$T_1$ modified in United States or over North Atlantic Ocean.
$T_2$ .....	Tropical Atlantic.
$NA_5$ .....	$T_2$ modified in the United States or over the Atlantic Ocean.
$NA_6$ .....	Do
$T_3$ .....	Tropical Pacific.
$NA_7$ .....	$T_3$ modified in the United States.

<sup>1</sup> Met. Zeit., 1932, Heft 6, S. 242-244.

<sup>2</sup> For a complete exposition of the significance of the different air-mass types see Willett, H.C., American Air Mass Properties, Papers on Physical Oceanography and Meteorology. Published by Massachusetts Institute of Technology and Woods Hole Oceanographic Institution, vol. 2, no. 2, Cambridge, Mass., June 1933.

<sup>3</sup> Kimball, Herbert H., and Hand, Irving F. The Use of Glass Color Screens in the Study of Atmospheric Depletion of Solar Radiation. MONTHLY WEATHER REVIEW, vol. 61, pp. 80-83, March 1933.